EA Tectonics and Geodynamics of the New Guinea Region Since the Triassic*

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Abstract

The New Guinea margin has experienced a complex geodynamic evolution as it is situated at the junction between the Tethyan and (proto-) Pacific tectonic domains. The chronology and nature of basin opening and closure, as well as the timing and style of collisions is critical for understanding the genesis of ore and hydrocarbon resources in the region. Detailed regional plate reconstructions in this area are difficult because no seafloor spreading histories are preserved, while remnants of multiple generations of back-arc and intra-oceanic subduction systems are dismembered along many suture zones in remote parts of New Guinea.

Discussion

We present a new plate tectonic reconstruction since the Triassic for this region, implemented in the open-source and cross-platform GPlates (www.gplates.org) software (Figure 1). This digital plate motion model is accompanied by new synthetic seafloor spreading histories consistent with block motions, as well as an evolving network of plate boundary topologies in 1 Myr intervals. The regional model is embedded in a new global model, and particularly significant updates to the eastern Tethyan reconstructions. These digital models allow us to extract the velocity field and the nature of plate boundary evolution, that we couple to High Performance Computing forward numerical models of mantle flow in CitcomS (Figure 1 and Figure 2) (https://geodynamics.org/cig/software/citcoms/). The incompressible (Boussinesq Approximation) (Figure 2) and pseudo-compressible (Extended Boussinesq Approximation) mantle convection is driven by the plate motions on the surface, and heating at the core-mantle boundary, capturing mantle evolution and a prediction of the mantle structure at present day. These models also allow us to extract the dynamic topography resulting from mantle flow (Figure 3), which has a time-evolving amplitude of several hundred meters.

Our plate reconstructions incorporate long-lived Andean style subduction along the New Guinea margin during the (Permian? -) Triassic, transitioning to back-arc opening from slab roll-back in the Mid Jurassic. This event detached the Sepik terrane, with seafloor spreading initiated by ~170-160 Ma in the Sepik back-arc basin. The spatial origin of the Sepik terrane along the margin remains unknown, hence we implement a simplified model. In addition, the roll-back and arc evolution likely represent the origin of the Philippine Arc. North-dipping subduction along the Sepik terrane initiated in the Mid to Late Cretaceous. Previous testing of end-member models of the Sepik terrane accretion indicates a collision in the Early Eocene, but this process was likely diachronous along the margin.

We highlight the need to validate plate reconstructions using other modelling approaches, ranging from mantle flow simulations to emerging landscape evolution models that test the implied erosional and depositional histories. The combination of data and modelling in digital community frameworks will remain critical in de-risking frontier exploration in Papua New Guinea and beyond, with much-needed geochronology and geochemistry still needed to unravel the geodynamic history of this tectonically complex region.

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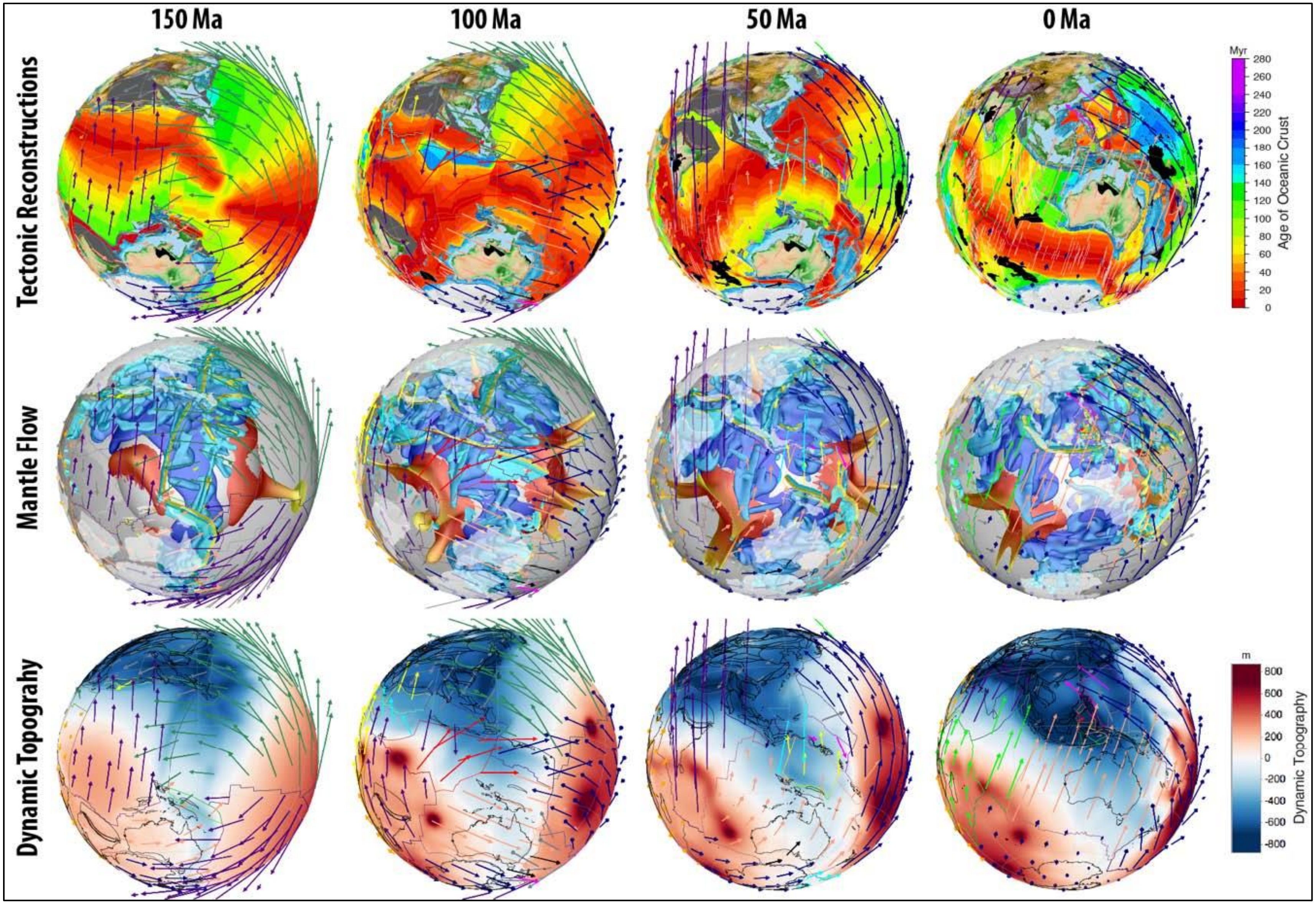

Figure 1. Tectonic reconstructions from Zahirovic et al., 2016 using the cross-platform community GPlates software [top] are applied as boundary conditions to numerical models of mantle flow following the method of Bower et al., 2015 and the model setup of Hassan et al., 2016 [middle], allowing us to estimate the dynamic topography acting on the surface [bottom].

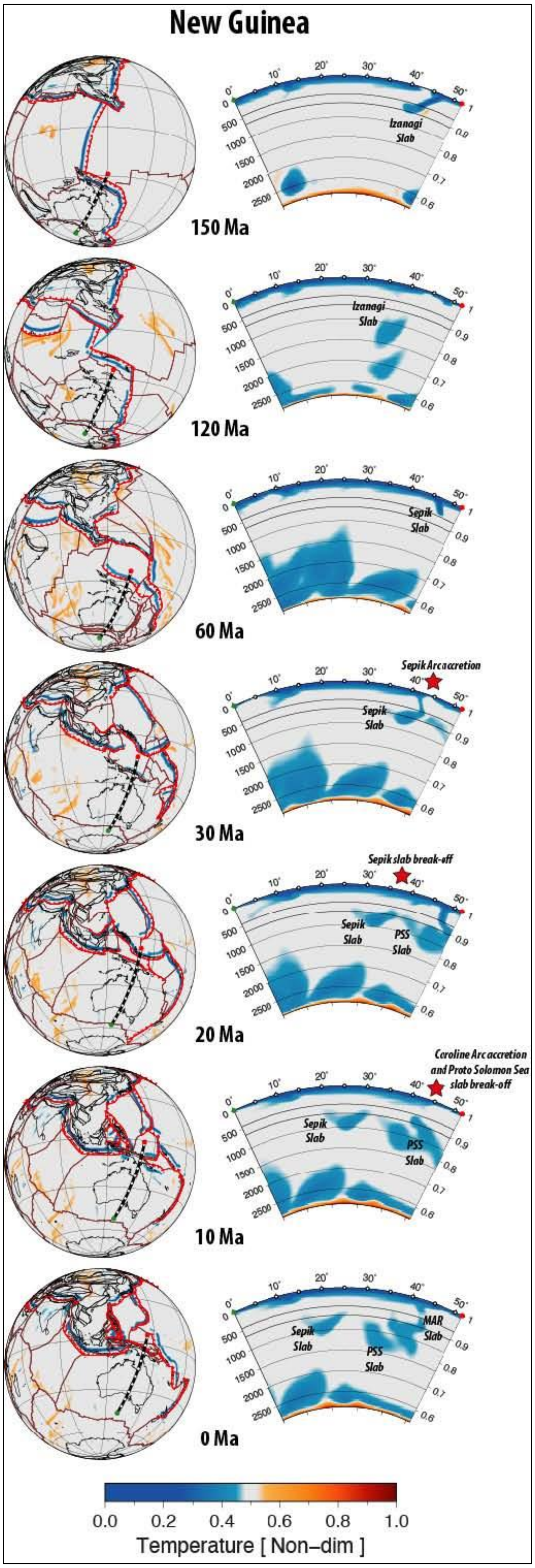

Figure 2. The numerical models (Boussinesq Approximation model output shown here) allow us to interrogate the subduction history and identify what subducted slabs are driving perturbations to the dynamic topography signal experienced by New Guinea and Australia.

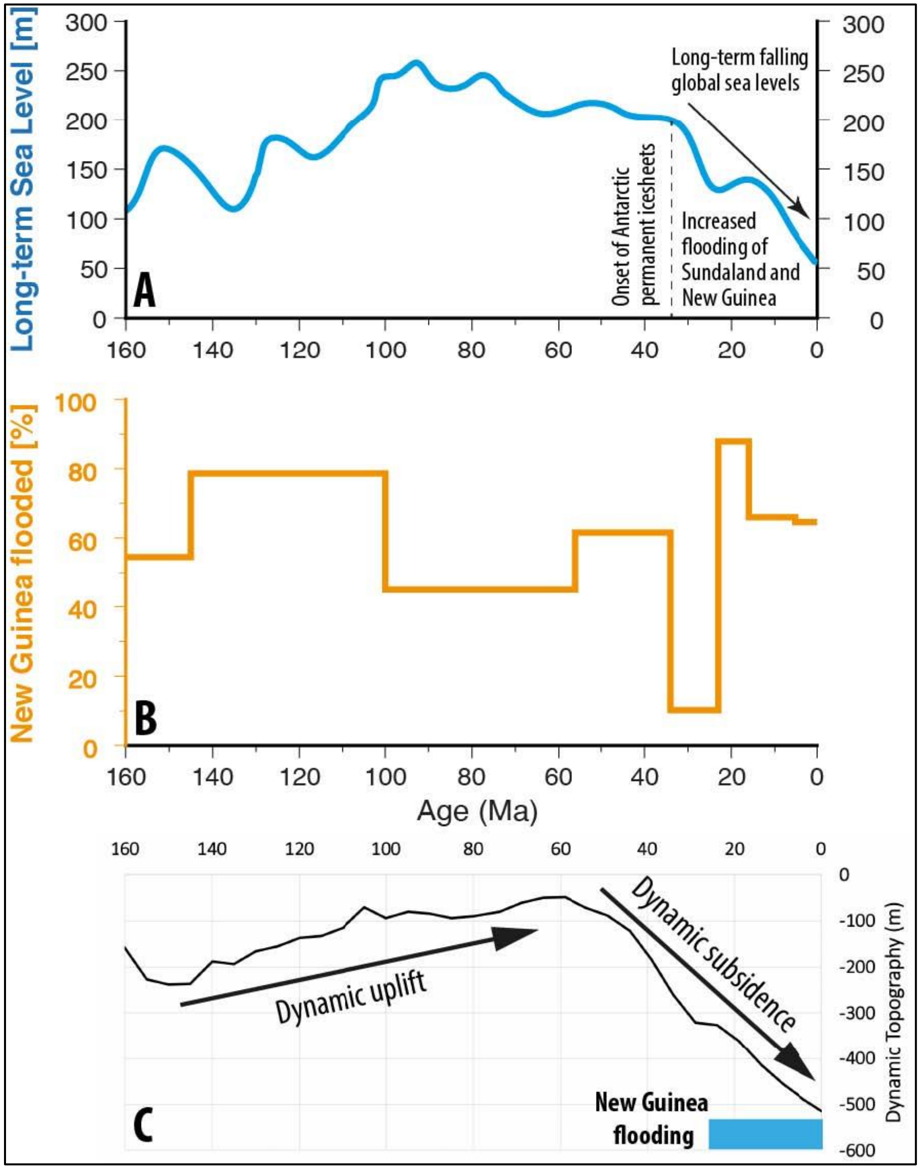

Figure 3. A) Long-term global sea levels highlight falling sea levels since ~35 Ma, following the formation of significant ice sheets in Antarctica, while the paleogeographic reconstructions (usually derived from stratigraphic interpretations) highlight a flooded (marine) environment for Papua New Guinea during this time. B) Paleogeographic reconstructions from Golonka et al., 2006; Norvick 2003; and Harrington et al., 2017 highlight the rise in long-term flooding of New Guinea since ~25 Ma. C) Dynamic topography from an Extended Boussinesq Approximation model, following the setup of Hassan et al., 2016; highlights broad dynamic uplift in the Early Cretaceous (as the Sepik back-arc basin grows), followed by strong dynamic subsidence in the Cenozoic due to Australia and New Guinea overriding the subducting slabs related to Sepik back-arc basin closure.